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XVIII. *On the application of liquids formed by the condensation of gases as mechanical agents.* By Sir HUMPHRY DAVY, Bart. Pres. R. S.

Read April 17, 1823.

ONE of the principal objects that I had in view, in causing experiments to be made on the condensation of different gaseous bodies, by generating them under pressure, was the hope of obtaining vapours, which, from the facility with which their elastic forces might be diminished or increased, by small decrements or increments of temperature, would be applicable to the same purposes as steam.

As soon as I had obtained muriatic acid in the liquid state, a body which M. BERTHOLLET supposed owed its power of being separated from bases by other acids, only to the facility with which it assumes the gaseous form, I had no doubt, as I mentioned in my last communication, that all the other gases which have weaker affinities or greater densities, and which are absorbable to any extent by water, might be rendered fluid by similar means; and, that the conjecture was founded, has been proved by the experiments made with so much industry and ingenuity by Mr. FARADAY, and which I have had the pleasure of communicating to the Society.

The elasticity of vapours in contact with the liquids from which they are produced, under high pressures by high temperatures, such as those of alcohol and water, is known to increase in a much higher ratio than the arithmetical one of the

temperature; but the exact law is not yet determined; and the result is a complicated one, and depends upon circumstances which require to be ascertained by experiment. Thus the ratio of the elastic force, dependent upon pressure, is to be combined with that of the expansive force dependent upon temperature; and the greater loss of radiant heat at high temperatures, and the developement of latent heat in compression, and the necessity for its re-absorption in expansion (as the rationale of the subject is at present understood) must awaken some doubts as to the economical results to be obtained by employing the steam of water under very great pressures, and at very elevated temperatures.

No such doubts, however, can arise with respect to the use of such liquids, as require for their existence even a compression equal to that of the weight of 30 or 40 atmospheres: and where common temperatures, or slight elevations of them, are sufficient to produce an immense elastic force; and when the principal question to be discussed, is whether the effect of mechanical motion is to be most easily produced by an increase or diminution of heat by artificial means.

With the assistance of Mr. FARADAY I have made some experiments on this subject, and the results have answered my most sanguine expectations. Sulphuretted hydrogen, which condenses readily at  $3^{\circ}$  F., under a pressure equal to that which balances the elastic force of an atmosphere compressed to  $\frac{1}{14}$ , had its elastic force increased so as to equal that of an atmosphere compressed to  $\frac{1}{17}$  by an increase of  $47^{\circ}$  of temperature. Liquid muriatic acid at  $3^{\circ}$ , exerted an elastic force equivalent to that of an atmosphere compressed to  $\frac{1}{20}$ ; by an increase of  $22^{\circ}$ , it gained an elastic

force equivalent to that of an atmosphere compressed to  $\frac{1}{25}$ ; and by a farther addition of  $26^{\circ}$ , an elastic force equivalent to that of air condensed to  $\frac{1}{40}$  of its primitive volume. These experiments were made in thick glass tubes hermetically sealed. The degree of pressure was estimated by the change of volume of air confined by mercury in a small graduated gage, and placed in a part of the tube exposed to the atmosphere, and the temperatures were diminished from the degree at which the gage was introduced, *i. e.* the atmospheric temperature by freezing mixtures; so that the temperature of the air within the gage could not be considerably altered; and as the elastic fluid surrounding the gage must have had a higher temperature than the condensed fluid, the diminution of the elastic force of the vapour from the fluids cannot be considered as overrated.

From the immense differences between the increase of elastic force in gases under high and low pressures, by similar increments of temperature, there can be no doubt that the denser the vapour, or the more difficult of condensation the gas, the greater will be its power under changes of temperature as a mechanical agent: thus carbonic acid will be much more powerful than muriatic acid. In the only experiment which has been tried upon it, its force was found to be nearly equal to that of air compressed to  $\frac{1}{20}$  at  $12^{\circ}$  F., and of air compressed to  $\frac{1}{36}$  at  $32^{\circ}$  degrees, making an increase equal to the weight of 13 atmospheres by an increase of 20 of temperature; and this immense elastic force of 36 atmospheres being exerted at the freezing point of water.\*

\* Since this Paper was read, Mr. FARADAY has ascertained that the vapour of ammonia at  $32^{\circ}$  exerts an elastic force equal to that of an atmosphere compressed

And azote, if it could be obtained fluid, would, there is no doubt, be far more powerful than carbonic acid ; and hydrogen, in such a state, would exert a force almost incalculably great, and liable to immense changes from the slightest variations of temperature.

To illustrate this idea, I shall quote an experiment on alcohol of sulphur.

The temperature of this body was raised 20 degrees above its boiling point, and its elastic force examined : it was found equal to less than that of air compressed to  $\frac{3}{4}$ . It was now heated to  $320^{\circ}$  under a pressure equal to that of air condensed to  $\frac{1}{77}$ , and a similar increment of 20 degrees added : its elastic force became equivalent to that of an atmosphere compressed to  $\frac{1}{895}$ .

I hope soon to be able to repeat these experiments in a more minute and accurate way ; but the general results appear so worthy the attention of practical mechanics, that I think it a duty to lose no time in bringing them forward even in their present imperfect state.

In applying the condensed gases as mechanical agents there will be some difficulty ; the materials of the apparatus must be at least as strong and as perfectly joined as those used by Mr. PERKINS in his high pressure steam engine : but the small differences of temperature required to produce an elastic force equal to the pressure of many atmospheres, will render the risk of explosion ex-

to  $\frac{1}{2}$  ; and at  $50^{\circ}$  to that of an atmosphere compressed to  $\frac{1}{65}$  : and that the vapour of nitrous oxide at  $32^{\circ}$  has an elastic force equal to that of an atmosphere compressed to  $\frac{1}{44}$  ; and at  $45^{\circ}$  to an atmosphere compressed to  $\frac{1.0}{51.3}$  nearly.

tremely small; and if future experiments should realise the views here developed, the mere difference of temperature between sunshine and shade, and air and water, or the effects of evaporation from a moist surface, will be sufficient to produce results, which have hitherto been obtained only by a great expenditure of fuel.

I shall conclude this communication by a few general observations arising out of this enquiry.

There is a simple mode of liquifying the gases, which at first view appears paradoxical, *namely, by the application of heat*; it consists in placing them in one leg of a bent sealed tube confined by mercury, and applying heat to ether, or alcohol, or water, in the other end. In this manner, by the pressure of the vapour of ether I have liquified prussic gas and sulphureous acid gas, the only two on which I have made experiments; and these gases in being reproduced occasioned cold.

There can be little doubt that these general facts of the condensation of the gases will have many practical applications. They offer easy methods of impregnating liquids with carbonic acid and other gases, without the necessity of common mechanical pressure.

They afford means of producing great diminutions of temperature, by the rapidity with which large quantities of liquids may be rendered aeriform; and as compression occasions similar effects to cold, in preventing the formation of elastic substances, there is great reason to believe that it may be successfully employed for the preservation of animal and vegetable substances for the purposes of food.

## APPENDIX TO THE PRECEDING PAPER.

*On the changes of volume produced in gases in different states of density, by heat.*

Read May 1, 1823.

**I**N investigating the laws of the elastic forces exerted by vapours or gases raised from liquids by increase of temperature under compression, one of the most important circumstances to be considered is the rate of the expansion, or what is equivalent, of the elastic force, in atmospheres in different states of density.

It has been shown by the experiments of M. M. DALTON and GAY LUSSAC, that elastic fluids of very different specific gravities expand equally by equal increments of temperature, or, as it may be more correctly expressed, according to the elucidations of M. M. DULONG and PETIT, that mercury and air, or gases, are equivalent in their expansions for any number of degrees in the thermometrical scale between the freezing and boiling points of water ; and the early researches of M. AMONTONS seemed to show that the increase of the spring or elastic force of air by increase of temperature, was in the direct ratio of its density. I am not however acquainted with any direct researches upon the changes of volume produced in gases in very different states of condensation and rarefaction by changes of temperature, and the importance of the enquiry, in relation to the subject of my last communica-

tion to the Society, induced me to undertake the following experiments.

Dry atmospherical air was included in a tube by mercury, and its temperature raised from  $32^{\circ}$  FAHRENHEIT to  $212^{\circ}$ , and its expansion accurately marked. The same volumes of air, but of double and of more than triple the density under a pressure of 30 and 65 inches of mercury, were treated in the same manner, and in the same tubes; and when the necessary corrections were made for the difference of pressure of the removed column of mercury, it was found that the expansions were exactly the same.

An apparatus was constructed, in which the expansions of rare air confined by columns of mercury were examined and compared with the expansions of equal volumes of air under common pressure; when it appeared, that for an equal number of degrees of FAHRENHEIT's scale, and between  $32^{\circ}$  and  $212^{\circ}$  they were precisely equal, whether the air was  $\frac{1}{2}$ ,  $\frac{1}{3}$ , or  $\frac{1}{6}$  of its natural density.

Similar experiments were made, but they were necessarily less precise, with air condensed six and expanded fifteen times, with similar results.